ABILITY OF THE FIREBRAT TO DAMAGE FABRICS AND PAPER[1]

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The firebrat (*Thermobia domestica* (P.)) is often confused with the silverfish (*Lepisma saccharina* L.) and much of the damage to fabrics and paper caused by these insects is blamed on the silverfish alone. Because the firebrat is also responsible for a great deal of this injury, an investigation was undertaken to test its ability to damage certain fabrics and papers. The experiments, which covered the period from Sept., 1938, to June, 1939, had the following objectives: To determine which of the common fibers used in textiles are preferred by the firebrat under starvation conditons; to study the relative efficiency for extending survival of these fibers; and to consider the ability of the firebrat to survive on a readily eaten paper.

There are numerous records of the damage caused by members of the Lepismatidæ, but few of them refer specifically to the firebrat. Jackson (1886) reported serious injury to heavily-sized paper by *T. domestica,* but stated that unsized paper was not damaged. McDaniel (1921) states that this species has been observed damaging glue and leather. Spencer (1930) writes that *T. domestica* was found in the laundry in the basement of a hospital in Vancouver in Sept., 1928. Adams (1933) observes that firebrats attack laundered clothes for the starch, and have the ability to live upon dry vegetable and animal materials of considerable variety. Twinn (1933) records that *T. domestica* has become increasingly important as a household pest in Canada, particularly in urban sections of Ontario and Quebec, and that it will feed upon artificial silk (rayon) goods. Back (1937) does not distinguish closely between damage caused by *L. saccharina* and by *T. domestica,* but states that they feed upon the sizing in paper, bookbindings, and wall paper, and upon starchy insula-

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tion materials, thin fabrics, particularly rayon, starched clothing, and lace curtains for the starch. Sweetman (1938) also writes that the firebrat feeds on starchy paper and starchy cloth. Hase (1938) discusses the damage to various types of paper by lepismatids but does not consider the work of *T. domestica* specifically. Weiss and Carruthers (1937) furnish much information on the injury to books and documents by lepismatids and provide an excellent bibliography.

At Ames, Iowa, the firebrat has been a nuisance in dormitories, rooming houses, and college buildings because of its attack on paper and cotton, woolen, and knitted silk and rayon materials.

MATERIALS AND METHODS:

The experimental insects used were adults, unselected except that they exceeded 7 mm. in length. They were reared in laboratory cultures under controlled conditions of 38° C. and 70 per cent relative humidity (Adams 1937).

The twenty-five fabrics used included seven kinds of fibers: cotton, jute, linen, ramie, rayon, silk, and wool; and three samples of paper, two filter papers and one typewriter paper. The names and characteristics of these materials follow:

COTTON

Mercerized; bleached, moderately sized, damask weave.
Organdy; bleached, permanent finish, plain weave.
Broadcloth; unbleached, very lightly sized, twill weave.

JUTE

Burlap; unbleached, plain weave, heavy weight.

LINEN

Toweling; unbleached, plain weave, closely woven.
Gauze; unbleached, loosely woven, theatrical gauze.

RAMIE

Unbleached, plain weave. (Ramie is a fiber obtained from the stem of the perennial *Bœhmeria nivea,* and is used as a cotton substitute.)

Rayon

Celanese; plain weave.
Cellulose acetate; plain weave.
Knitted regenerated cellulose.
Regenerated cellulose; plain weave.
Rayons No. 1 to 8; satin weave, heavy weight.
No. 1 to 7 were given a sizing treatment.
No. 1 to 4 were also treated with fluosilicate compounds.
No. 5 was also treated with tetramethylthiuram monosulfide.
No. 6 was also treated with tetramethylthiuram disulfide.
No. 8 was untreated.

Silk

Cultivated; bleached, crepe weave.
Knitted; cultivated.
Wild; unbleached, plain weave.

Wool

Partly scoured; unbleached, coarse.
Flannel; bleached, twill weave, fine.
Casein and wool fabric; (50 per cent wool, 50 per cent casein) plaid, twill weave.

Paper

Filter paper No. 40, Whatman; diameter 12.5 cms., 0.000174 gm. ash.
Filter paper No. 41, Whatman; diameter 9.0 cms., 0.0001 gm. ash.
Medium weight typewriter bond paper; white, 16 pound.

Each experiment consisted of a series of ten insects, each insect in an individual open shell vial 25×50 mm. Twenty-four hours of starvation preceded the beginning of each experiment and control, to encourage prompt feeding.

The trays of experimental insects were kept in a constant temperature cabinet maintained at a temperature of 38° C. and 70 per cent relative humidity which were approximately the conditions for maintenance of the cultures.

Each vial of a given experiment contained a piece of the

material, cut with edges as smooth as possible, and weighing approximately 96 mg; the piece was folded or creased transversely and placed on edge in the bottom of the vial.

The conditions for the control series duplicated in every way those for the experimental series, except that a bent strip of lightweight sheet aluminum was inserted to serve as a climbing and resting surface similar to that furnished by the fabric or paper.

There was no actual food in any of the experimental or control vials.

Observations were made every twenty-four hours; only such feeding as was visible to the naked eye was recorded, since microscopic damage was considered to be of little practical significance.

All experiments were replicated, the usual number of replications being 4. The number of insects used in each series of tests is given in Table II.

TABLE I

PROPORTION OF FIREBRATS WHICH FED AND EXTENT OF FEEDING ON FABRICS AND PAPERS

Material	Percentage of insects which fed	Extent of feeding
Jute	0	None
Wool, partly scoured	"	"
Casein and wool	1–10	Very light
Rayon No. 6	"	" "
Cultivated silk	"	" "
Mercerized cotton	11–20	Very light
Rayons No. 1, 2, 3, 4, 5, 7, & 8	"	" "
Celanese	31–40	Very light
Cellulose acetate	"	" "
Ramie	"	" "
Filter paper No. 40	"	" "
Wild silk	41–50	Moderate
Wool flannel	"	Very light
Cotton broadcloth	51–60	Moderate
Cotton organdy	61–70	Moderate
Linen toweling	"	"
Filter paper No. 41	"	Very light
Knitted silk	71–80	Moderate
Linen gauze	91–100	Heavy
Knitted regenerated cellulose	"	Moderate
Regenerated cellulose, plain weave	"	Heavy
Typewriter bond paper	"	"

Results:

The number of insects feeding on a fabric or paper was calculated on the percentage basis; in addition, the following categories of extent of feeding were recognized: 1. none; 2. very light; 3. moderate; and 4. heavy. These data are presented in Table I.

For each insect the period from time of exposure to the material to the first appearance of feeding was recorded. These

TABLE II

Survival of Firebrats on Fabrics and Papers

Experimental materials	Survival on experimental material			Survival on control		
	No. of insects	Mean survival	Range	No. of insects	Mean survival	Range
		Days	*Days*		*Days*	*Days*
Mercerized cotton	50	14	3–24	50	13	1–25
Cotton organdy	40	14	1–29	40	13	6–29
Cotton broadcloth	50	15	6–27	50	15	8–31
Jute burlap	40	14	6–32	40	12	4–23
Linen toweling	60	16	7–33	60	13	1–32
Linen gauze	40	26	7–76	40	14	3–32
Ramie	40	13	3–25	40	14	6–28
Celanese	40	14	7–29	40	15	2–29
Cellulose acetate	40	14	4–22	40	13	4–26
Knitted regenerated cellulose	40	29†	8–69	40	14	7–21
Regenerated cellulose, plain weave	50	24	5–51	50	15	1–31
Rayon No. 1	40	15	5–30	40	15	6–28
Rayon No. 2	40	17	4–48	40	16	1–37
Rayon No. 3	40	18	6–42	40	18	4–37
Rayon No. 4	40	17	3–39	40	16	4–31
Rayon No. 5	40	18	6–35	40	15	4–31
Rayon No. 6	40	16	5–32	40	14	1–30
Rayon No. 7	40	15	5–23	40	13	3–33
Rayon No. 8	68	16	4–34	50	14	1–33
Cultivated silk	50	16	5–31	50	13	1–26
Knitted silk	40	15	6–36	40	14	6–27
Wild silk	50	14	4–25	50	14	7–25
Wool, partly scoured	50	16	4–34	50	14	1–31
Wool flannel	40	14	7–23	40	14	5–24
Casein and wool	20	14	6–33	20	12	4–26
Filter paper No. 40	80	14	3–33	80	13	1–27
Filter paper No. 41	60	18*	5–42	60	14	3–33
Medium typewriter bond paper	605	34†	1–117	670	14	1–37

* Statistically distinct from the control when probability is 0.05.
† Statistically distinct from the control when probability is 0.01.

figures are of much consequence only for the materials on which a large percentage of insects fed. The mean pre-feeding periods for these four materials are as follows: Linen gauze, 6 days; knitted regenerated cellulose, 4 days; regenerated cellulose, plain weave, 3 days; and typewriter bond paper, 4 days.

Survival data are presented in Table II, with the mean survival period and range in days for each material placed opposite the mean survival period and range for its respective control group. By use of the *t*-test this mean survival period for a given material was compared with that for the control group.

DISCUSSION:

The two fabrics, jute and partly scoured wool (Table I), on which there was no feeding, may have been unattractive to the insects because of the stiff, wiry composition of the fiber. The grease remaining in the partly scoured wool may be an additional factor to help explain its position in the table, for it has not been reported that firebrats have a liking for materials of a fatty nature.

In the next group, in which feeding is very light and the number feeding is small, there are three fabrics, casein and wool, rayon No. 6, and cultivated silk. Although dried milk is used as a food for firebrat cultures, casein as a fiber does not appear to be attractive to this insect. More thorough scouring of the wool does not add materially to the amount of feeding on it. It might be expected that the cultivated silk would be more seriously damaged, since it is a thin fabric, upon which firebrats have been observed to feed (Back 1937). However, this particular sample was of a hard-twist, closely woven thread, and these characteristics probably account for its inclusion in this group.

It was predicted that the mercerized cotton would be placed among the materials seriously attacked for the sizing they contain. However, this material appeared to have little attraction for the firebrat.

While the categories that have been arbitrarily established separate rayon No. 6 from the seven other rayons of the same type, the extent of feeding on the eight samples was practically identical, and the percentage of insects that fed was not great.

Since the eight samples, including the untreated fabric, occupy approximately the same position in the table, it is considered that the heavy, slick texture of the material comprising these rayon samples is the deciding factor in their comparative freedom from attack.

Celanese, cellulose acetate, and ramie, the fabrics on which 31 to 40 per cent of the insects fed and to a very light extent, evidently are those to which slight, occasional damage can be expected.

The tests on filter paper were interesting because of the absence of sizing in this type of paper. Filter paper No. 40 has a thicker, tougher texture than paper No. 41, which probably accounts for the difference in the percentage of feeding. The extent of feeding, classified in both cases as "very light," was difficult to determine because of the possibility of considerable almost invisible surface feeding. The occurrence of such feeding may help to explain the significant difference in survival time between No. 41 and the control which will be discussed later.

Damage to wild silk, cotton broadcloth, cotton organdy, and linen toweling is occasional to rather frequent, and of an extent that would be of some concern where these fabrics are stored in firebrat-infested places for long periods of time. Although this broadcloth was only lightly sized, the starchy material used in sizing probably attracted the insects a very little. The cotton organdy was more attractive, it is suggested, not primarily because of a different sizing given to produce a "permanent finish," but because of the very fine threads which made feeding easier. Linen is possibly the most attractive fiber thus far discussed; and although this sample of linen toweling was a rather heavy, stiff material, the experimental data placed it in a group where more significant damage occurred.

The attacks on knitted silk and knitted regenerated cellulose, observed in 71 to 80 per cent and 91 to 100 per cent, respectively, of the cases and to a moderate extent, represent a more important economic problem than those on any other fabric in this list; for with a knitted material, the cutting of a single thread, as was observed to occur in many instances, causes, after strain, damage to the strength and appearance of the fabric all out of proportion to the original injury.

Linen gauze, regenerated cellulose, plain weave, and medium typewriter bond paper, the three materials upon which feeding was heavy and undertaken by 91 to 100 per cent of the individuals, can be said to be definitely attractive to the firebrat. The points of injury were often numerous and involved a large area. Where linen gauze is used in curtains and draperies, regenerated cellulose, plain weave, is used in wearing apparel, and typewriter bond is the paper for stored records and manuscripts, the presence of firebrats will be a distinct nuisance and will cause severe loss.

Regarding all of these materials, medium typewriter paper, knitted and plain weave regenerated cellulose and linen gauze have been shown to be especially attractive to firebrats, while cotton and silk are attacked if the texture of the material is particularly suitable for feeding, as is the case with cotton organdy and knitted silk. A sizing-free paper is not seriously damaged.

That the firebrat is able to obtain some nourishment from knitted regenerated cellulose and typewriter bond paper is shown by the *t*-test which demonstrates a highly significant difference between mean survival in days on experiment and control (Table II). Survival on regenerated cellulose, plain weave, and on linen gauze was more variable; and the *t*-test failed to reveal significant differences in spite of rather large actual differences between the means. However, there is a close approach to significance, especially for the difference between regenerated cellulose, plain weave and its control. It seems probable that additional experimental data would demonstrate the ability of the firebrat to extend its life on these fabrics. Although mean survival on filter paper No. 41 proved significantly different than the mean survival on the control, the fact that a mean survival of 18 days was reached in one control of smaller sample size (control for rayon No. 3) lends some doubt to the reality of this difference.

SUMMARY:

The damage by *Thermobia domestica* to twenty-five fabrics of seven fibers (cotton, jute, linen, ramie, rayon, silk, and wool) and to three papers (two low ash filter papers and one medium typewriter bond) was investigated.

Medium typewriter bond paper, regenerated cellulose, either knitted or plain weave, and linen were the materials most heavily damaged; cotton and silk were attacked if the texture of the material was very suitable for feeding. The typewriter bond was the only one of the 3 papers tested that was seriously damaged.

The significance of the ability of the firebrat to survive on these materials was tested statistically by comparing data for the survival period on the material with the survival data for the corresponding starvation control. The differences in the mean survival periods were significant for knitted regenerated cellulose and medium typewriter bond paper.

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